Appendix B

APPENDIX B

The present patent application is a continuation of and claims priority to

Applicant's pending U.S. patent application Serial No. 09/973,529 ("the '529 application"), filed

October 9, 2001. The '529 application is a continuation-in-part of and claims priority to

abandoned U.S. patent application Serial No. 09/686,735 ("the '735 application"), filed

October 10, 2000.

The table below applies the terms of Applicant's new claims 23-26 to the

disclosure of the '735 application. This table demonstrates that the '735 application fully

disclosed the subject matter of Applicant's claims 23-26, and that the effective filing date of

those claims is October 10, 2000.

All page citations in the table below are to the specification of the '735

application.

Claim Limitation	Disclosure In The '735 Application
23. A method for determining a parameter of interest of a subsurface region of earth formations comprising:	"The present invention is a system and method to measure formation properties and in particular to predict the pore pressure [an example of a parameter of interest] in the vicinity of or in the formation ahead of the drill bit by analyzing acoustic waves that are emitted from the bottom hole assembly (BHA) and which pass through and are reflected from the formation." (Page 5.)
(a) obtaining seismic survey information about the subsurface region;	"Data presently used to estimate the pore pressure profile at a proposed well location include offset well data, surface seismic data, seismic-while-drilling data, and geologic models." (Pages 1-2.)
	"The present invention is a system and method to measure formation properties and in particular to predict the pore pressure in the vicinity of or in the formation ahead of the drill bit by analyzing acoustic waves that are emitted from the bottom hole assembly (BHA) and which pass through and are reflected from the formation. The acoustic waves in the frequency range of 10 Hz to 20 kHz can be generated passively such as by the drill bit in the drilling process or actively by placing a controlled acoustic signal generator in the BHA. When active frequency sources are used, a much wider range of frequencies may be

Claim Limitation	Disclosure In The '735 Application
	employed such as from approximately 0.01 to greater than 100 kHz. Acoustic detectors are mounted along the BHA to detect both compressional (P) and shear (S) waves." (Page 5.)
	"The system for measuring the pore pressure ahead of the drill bit is shown in Figure 1a. The measurement system is comprised of the following components: a source for generating acoustic signals at or near the drill bit; a receiver array mounted on the bottom hole assembly (BHA) for detecting the signals generated by the source; hardware and software for signal processing on the BHA, and a telemetry system for transmitting the pore pressure information to the drill rig." (Pages 7-8.)
(b) identifying a plurality of interpreted seismic horizons of interest from the obtained survey information;	*Figure 1a shows a Reflector, which is the boundary between a first formation (Fm. A) and a second formation (Fm. B). The Reflector is an interpreted seismic horizon of interest identified from obtained survey information.*
	"Several receivers are positioned along the BHA to detect the signals (shown as the Reflected wavefronts (C) in Figure 1a) reflected from the formation ahead of the drill bit. These are the reflected waves from changes in the formation ahead of the BHA due to waves that are emitted from the source (either an active source or the drill bit noise). The receivers are positioned at varying distances from the source. By establishing the time of arrival of the same signal at each receiver, the distance from the source to the acoustic reflector in the formation can be determined using the methods of normal moveout (NMO). This is analogous to the methodology used in Surface seismic reflection surveys. (Sheriff, R.E., Geldart, L.P., 1982, *Exploration Seismology Volume 1, History, Theory, and Data Acquisition*, Cambridge Univ. Press.)" (Page 10.)
	"The signals traveling through the formation can be classified into two types, direct arrivals and reflected signals. The direct arrivals travel from source to receivers through the formation along the bore hole. This signal is identified by its linear move out and can be used to determine the frequency dependent velocity of the formation adjacent to the BHA. This velocity is used to determine the distance to the first acoustic reflector ahead of the drill bit." (Page 10.)
	"Seismic-while-drilling (SWD) is a method for estimating formation velocity above and below the drill-bit during the drilling process." (Page 2.)
	"Compared to pore pressure prediction using surface seismic methods, the main advantages of SWD are that the depth to sub-surface reflectors is better constrained and vertical resolution is

Claim Limitation	Disclosure In The '735 Application
	improved." (Page 3.)
	"Bed boundaries, heterogeneities and other properties of rocks that serve as sources of acoustic impedance contrast will reflect some of the energy back to the BHA where receivers detect the signal. The depth of penetration from the source on the BHA to the reflectors in the formation will vary from several tens of feet when operating in the ultrasonic frequency range to several hundreds of feet when operating in the sonic frequency range. If the drill bit noise spectrum is used as the source, measurement of the drill bit noise spectrum directly can be used to cross-correlate the reflected signal in order to determine the time origin and the distance to the reflector. (Sheriff, R.E., Geldart, L.P., 1983, *Exploration Seismology Volume 2, Data-Processing and Interpretation*, Cambridge Univ. Press.) If an active source is used, techniques similar to those used in reflection seismology or ground penetrating radar can be used to determine the distance to the reflectors in the formation. (Sheriff, R.E., Geldart, L.P., 1982, *Exploration Seismology Volume 1, History, Theory, and Data Acquisition*, Cambridge Univ. Press.)" (Pages 8-9.)
	"The signal arriving from acoustic reflectors in the formation is recognized by the normal hyperbolic move out." (Page 11.)
(c) obtaining estimated seismic velocities corresponding to at least one interval between at least one pair of said plurality of seismic horizons, wherein the obtained seismic velocities are selected from the group consisting of:	"Seismic-while-drilling (SWD) is a method for estimating formation velocity above and below the drill-bit during the drilling process." (Page 2.)
	"The signal is detected by cross correlating the signal propagating through the earth formation with the signal that has traveled along the drill string (Staron, P., Arens, G., and Gros, P., 1988, *Method of instantaneous acoustic logging within a wellbore*, U.S. Patent No. 4,718,048). Usually the signal at a single frequency (typically 50 Hz) is detected. Inversion processing, analogous to surface seismic processing, is used to estimate the acoustic impedance and velocity of *intervals* below the drill bit." (Page 3 (emphasis added).)
	"Thus, an alternate configuration for implementation of the current invention for measuring the pore pressure ahead of the drill bit is to measure the velocity of the waves traveling through the formation and reflected back to the receivers on the bottom hole assembly as a function of frequency. Following standard practice, the velocity can be determined from the time of arrival of the wave front at the receiver." (Pages 14-15.)

Claim Limitation	Disclosure In The '735 Application
(i) S-wave velocity data generated from normal moveout (NMO) velocity analysis,	"Acoustic detectors are mounted along the BHA to detect both compressional (P) and shear *(S) waves*." (Page 5 (emphasis added).) "Ideally, receivers for measuring compressional [P] waves and shear [S] waves should be mounted on the BHA." (Page 9.) "Formation velocity is estimated with seismic data using *normal moveout* (i.e., the travel time difference to one subsurface point from multiple offset records)." (Page 2 (emphasis added).) "By establishing the time of arrival of the same signal at each receiver, the distance from the source to the acoustic reflector in the formation can be determined using the methods of *normal moveout (NMO)*." (Page 10.) "The signal arriving from acoustic reflectors in the formation is recognized by the normal hyperbolic move out." (Page 11.)
(ii) P-wave velocity data from VSP look-ahead inversion, and (iii) S-wave velocity data from VSP look-ahead inversion;	"Acoustic detectors are mounted along the BHA to detect both compressional (P) and shear (S) waves." (Page 5.) "Ideally, receivers for measuring compressional [P] waves and shear [S] waves should be mounted on the BHA." (Page 9.) "Increased resolution can be achieved by employing Vertical Seismic Profiling (*VSP*). (Payne, Michael A., 1994, *Looking Ahead with Vertical Seismic Profiles*, in Geophysics, Vol. 59, No. 8, pp. 1182-1191.) In *VSP*, geophones are lowered into the borehole so that the precise depth of the geophone is known and only the one way seismic travel times need to be measured." (Page 4 (emphasis added).) *The specification is replete with passages that disclose obtaining look-ahead velocity data, including inversion processing of such data. The following passages are exemplary:* *Figure 1a and its corresponding description disclose a bottom hole drilling assembly that is used to obtain velocity data from acoustic waves that are reflected by the Reflector, which is ahead of the assembly.* "Several receivers are positioned along the BHA to detect the signals (shown as the Reflected wavefronts (C) in Figure 1a) reflected from the formation *ahead of the drill bit*." (Page 10.) "Seismic-while-drilling (SWD) is a method for estimating formation velocity above and *below the drill-bit* during the drilling process." (Page 2 (emphasis added).) "The signal is detected by cross correlating the signal

Claim Limitation	Disclosure In The '735 Application
	propagating through the earth formation with the signal that has traveled along the drill string (Staron, P., Arens, G., and Gros, P., 1988, Method of instantaneous acoustic logging within a wellbore, U.S. Patent No. 4,718,048). Usually the signal at a single frequency (typically 50 Hz) is detected. *Inversion processing*, analogous to surface seismic processing, is used to estimate the acoustic impedance and *velocity* of intervals below the drill bit." (Page 3 (emphasis added).)
(d) calibrating the estimated seismic velocities to the parameter of interest; and (e) using the results of said calibration and the obtained seismic velocities to obtain the parameter of interest at any location within the seismic survey.	*The specification contains numerous disclosures of calibrating estimated seismic velocities to a parameter of interest (e.g., pore pressure) and using the results of this calibration and the obtained velocities to obtain the parameter of interest at any location in the survey. The passages cited below are exemplary:* "Data presently used to estimate the pore pressure profile at a proposed well location include offset well data, surface seismic data, seismic-while-drilling data, and geologic models. Pressure measurements from nearby wells can provide the most accurate pre-drill pressure information, but for remote locations, these data are not available. Pore pressure estimation from surface seismic is based on an empirical relationship between the velocity of sound waves in the formation (estimated with the seismic data) and pore pressure with assumptions for lithology (formation composition). (Bowers, G.L., 1994, *Pore Pressure Estimation from Velocity Data: Accounting for Overpressure Mechanisms Besides Undercompaction*, 1994 IADC/SPE Drilling Conf., SPE 27488.) Formation velocity is estimated with seismic data using normal moveout (i.e., the travel time difference to one subsurface point from multiple offset records). Formation velocity is a function of the elastic moduli and density of the rock and generally increases with depth as rocks become more and more compacted. An increase in pore pressure with depth often coincides with a decrease in this increasing velocity trend (or even an actual decrease in velocity with depth) because the higher pore pressure is associated with less compacted rock." (Pages 1-2.) "The signal is detected by cross correlating the signal propagating through the earth formation with the signal that has traveled along the drill string (Staron, P., Arens, G., and Gros, P., 1988, *Method of instantaneous acoustic logging within a wellbore*, U.S. Patent No. 4,718,048). Usually the signal at a single frequency (typically 50 Hz) is detected. Inversion processing, analogous to surface seismic processing, is used to estimate the acoustic impedance and velocity of intervals below the drill bit The pore pressure is then estimated using the same velocity-pore pressure

Claim Limitation	Disclosure In The '735 Application
	empirical relationships as with surface seismic data." (Page 3.)
	"Acoustic detectors are mounted along the BHA to detect both compressional (P) and shear (S) waves. The pore pressure can be derived from the analysis of the frequency dependence of the P-wave amplitudes and/or the change in velocities of the wave signals and/or from Poisson's ratio calculated from the ratio of the S-wave and P-wave velocities. Analysis of data from laboratory measurements of acoustic attenuation on sandstone rocks at variable pore pressures implied that pore pressure at reservoir depths could be determined to within a mud weight of one tenth pound per gallon. Other formation properties typically derived from the analysis of wave properties such as fluid properties and permeability as is customary in acoustic open hole well logging can also be derived from the analysis of the acoustic waves." (Page 5.)
	"The present invention also includes a method to determine the pore fluid pressure in the vicinity of a drill bit located on a bottom hole assembly (BHA). The method includes the steps of generating wave signals of varying frequencies, detecting these signals after they travel through the earth formation, or are reflected from the earth formation hi the vicinity of the drill bit, determining the frequency dependent properties such as attenuation or velocity of the wave signals, and determining the pore fluid pressure in the vicinity of the BHA." (Page 6.)
	"Several mechanisms have been proposed to account for the frequency dependent wave propagation properties of fluid filled porous rocks (see for example, Dvorkin, J., Nolen-Hoeksema, R., and Nur, A., 1994, *The Squirt Flow Mechanism: Macroscopic Description*, Geophysics, vol. 59, #3, pp. 428-438; Dvorkin, J. Mavko, G., and Nur, A., 1995, *Squirt Flow in Fully Saturated Rocks*, Geophysics, vol. 60, #1, pp. 97-107.) According to these studies, the probable mechanisms for the observed frequency dependent wave propagation properties include the Biot slow wave mechanism and the squirt flow mechanism. In either case, these mechanisms result in a frequency dependent velocity as well as a frequency dependent attenuation and both will vary with the pore pressure. Thus, an alternate configuration for implementation of the current invention for measuring the pore pressure ahead of the drill bit is to measure the velocity of the waves traveling through the formation and reflected back to the receivers on the bottom hole assembly as a function of frequency. Following standard practice, the velocity can be determined from the time of arrival of the wave front at the receiver." (Pages 14-15.)

Claim Limitation	Disclosure In The '735 Application
	"An alternative step of the present method is to determine the pore pressure is from the calculation of Poisson's ratio. This can be calculated from the ratio of the measured compressional and shear wave velocities. Christensen and Wang (Christensen, J. I., and Wang, H. F., 1985, *The influence of pore pressure and confining pressure on dynamic elastic properties of Berea sandstone*, Geophysics, vol. 50, #2, pp. 207-213) reported measurements of the compressional and shear wave velocities at ultrasonic frequencies for sandstone rocks under variable pore pressure. These experimental results are shown in Figure 4. The red lines drawn over the data of Christensen and Wang show lines of constant pore pressure. The ratio υ_p/υ_s increases by approximately 10% as the pore pressure increases from a negligible value up to the confining pressure. Christensen and Wang performed their measurements using ultrasonic frequencies. From the published experimental results in the literature, the frequency dependent attenuation associated with pore pressure are found to be larger at acoustic frequencies than at ultrasonic frequencies. By analogy, it is likely that an increased range of υ_p/υ_s with variable pore pressure may exist in the sonic frequency range." (Page 15.)
	"Information on formation properties other than pore pressure can also be obtained with the invention disclosed herein. Lithology and fluid content are often estimated from S-wave and P-wave characteristics of the formation referenced. Therefore, lithology and fluid content of the formation adjacent to and ahead of the BHA can be determined with the invention disclosed herein. Formation permeability can be determined from the propagation characteristics of Stoneley (tube) waves that travel along a borehole (Williams, D.M., et al, 1984, *The Long Spaced Acoustic Logging Tool*, SPWLA 25th Annual Logging Symposium, Paper T). Stoneley waves are a subset of the direct borehole signal described in the present invention and can be used to determine formation permeability adjacent to the BHA. (Pages 15-16.)

Claim Limitation	Disclosure In The '735 Application
24. The method of claim 23 wherein the obtained seismic velocities are S-wave velocity data generated from normal moveout (NMO) velocity analysis.	"Acoustic detectors are mounted along the BHA to detect both compressional (P) and shear *(S) waves*." (Page 5 (emphasis added).) "Ideally, receivers for measuring compressional [P] waves and shear [S] waves should be mounted on the BHA." (Page 9.) "Formation velocity is estimated with seismic data using *normal moveout* (i.e., the travel time difference to one subsurface point from multiple offset records)." (Page 2 (emphasis added).) "By establishing the time of arrival of the same signal at each receiver, the distance from the source to the acoustic reflector in the formation can be determined using the methods of *normal moveout (NMO)*." (Page 10.) "The signal arriving from acoustic reflectors in the formation is recognized by the normal hyperbolic move out." (Page 11.)

Claim Limitation	Disclosure In The '735 Application
25. The method of claim 23 wherein the obtained seismic velocities are P-wave velocity data from VSP look-ahead inversion. 26. The method of claim 23 wherein the obtained seismic velocities are S-wave velocity data from VSP look-ahead inversion.	"Acoustic detectors are mounted along the BHA to detect both compressional (P) and shear (S) waves." (Page 5.) "Ideally, receivers for measuring compressional [P] waves and shear [S] waves should be mounted on the BHA." (Page 9.) "Increased resolution can be achieved by employing Vertical Seismic Profiling (*VSP*). (Payne, Michael A., 1994, *Looking Ahead with Vertical Seismic Profiles*, in Geophysics, Vol. 59, No. 8, pp. 1182-1191.) In *VSP*, geophones are lowered into the borehole so that the precise depth of the geophone is known and only the one way seismic travel times need to be measured." (Page 4 (emphasis added).) *The specification is replete with passages that disclose obtaining look-ahead velocity data, including inversion processing of such data. The following passages are exemplary:* *Figure 1a and its corresponding description disclose a bottom hole drilling assembly that is used to obtain velocity data from acoustic waves that are reflected by the Reflector, which is ahead of the assembly.* "Several receivers are positioned along the BHA to detect the signals (shown as the Reflected wavefronts (C) in Figure 1a) reflected from the formation *ahead of the drill bit*." (Page 10.) "Seismic-while-drilling (SWD) is a method for estimating

Claim Limitation	Disclosure In The '735 Application
	formation velocity above and *below the drill-bit* during the drilling process." (Page 2 (emphasis added).) "The signal is detected by cross correlating the signal propagating through the earth formation with the signal that has traveled along the drill string (Staron, P., Arens, G., and Gros, P., 1988, Method of instantaneous acoustic logging within a wellbore, U.S. Patent No. 4,718,048). Usually the signal at a single frequency (typically 50 Hz) is detected. *Inversion processing*, analogous to surface seismic processing, is used to estimate the acoustic impedance and *velocity* of intervals below the drill bit." (Page 3 (emphasis added).)